Strain generation and control on ultrashort time and length scales

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Optical excitation of solids allows for the generation of tailored strain fields on ultrashort time and length scales. Such strain fields are frequently generated in order to study fundamental aspects of lattice dynamics and phonon propagation, as well as the coupling of lattice excitations to other degrees of freedom in the solid, e.g. charge and orbital order or magnetic excitations. In our talk we discuss concepts of functionalization of coherent strain fields in solids that may pave the way for a new class of devices where strain controls, e.g., optical and/ or magnetic properties.

A key element in strain based applications is spatiotemporal control of the strain amplitude. In the first part of our talk, we discuss general aspects of lattice deformation by exemplarily deriving the linear thermal expansion coefficient of so-called Air-Gap Heterostructures (AGHs). AGHs consist of a 50 nm – 100 nm thin semiconductor (AlGaAs) membrane that is suspended from a GaAs substrate by 5 nm high nanopillars. The sample deformation is derived from temperature dependent XRD measurements and compared to similar data obtained on bulk materials. In addition we discuss the dynamic deformation which is determined in time-resolved XRD experiments. Both static and dynamic experiments reveal a strong impact of nanostructuring on the elastic properties of the sample.

In the second part of our talk we present a new method for spatiotemporal strain control in thin films and nanostructures. A femtosecond laser excitation inscribes a transient grating (TG) in a thin metallic film which is subsequently probed by hard x-ray photons under grazing incidence geometry. We will show that the diffracted x-ray intensity directly correlates with the amplitude of the optically induced surface excursion, thus allowing for measurements of transient deformations with sub-Å resolution. The transient deformation is decomposed in several acoustic modes and a thermal background. By using a second TG excitation and by controlling the spatial and temporal overlap of both excitations we gain full control over amplitude and phase of the coherent modes. On top we demonstrate coherent control of the incoherent thermal background, which is the main contribution to the diffraction signal. Finally we discuss possible applications of our method for new active x-ray optics by demonstrating a flexible temporal gate for hard x-ray pulses that may be used as pulse picker or ultrafast x-ray switch.